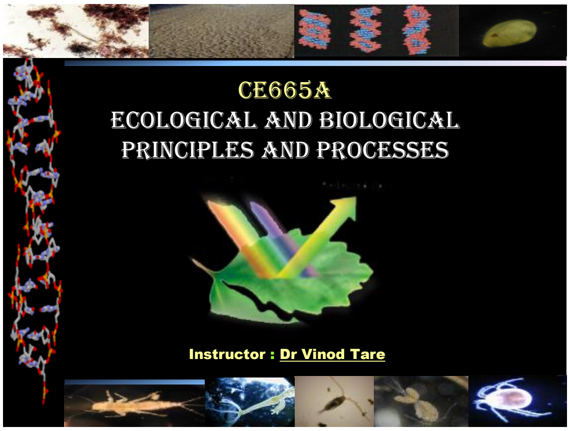


Emergence of Environmental Science/ Engineering/ Management Discipline

- **Public Health Engineering**
  - Water Supply ⇨ Civil Engineering
- **Sanitary Engineering**
  - Water Supply and Sanitation ⇨ Civil Engineering
- **Environmental Engineering and Management**
  - Inter Disciplinary Infra-structural Engineering

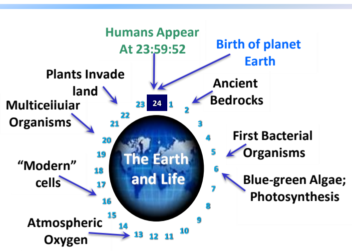
Environmental Science/Engineering/ Management Discipline

- **Multidisciplinary or Interdisciplinary**
  - Various disciplines of Science or Engineering or Management
- **Several Professions and Sectors**
  - Industry, Business, Academics and Research, Policy Making, Planning, Judiciary, Implementation/Administration, Journalism; Government/Semi government or Public/ Private Sector/NGOs
- **Preventive Activities, Control Activities, Remedial Activities ⇨ Resource Conservation, Sustainable Development; "End of the Pipe" Solutions; Regeneration**

Environmental Engineering and Management Programme

- **CE 602: Mathematics**
  - Basic Preparatory Course
- **CE 664: Physicochemical Principles and Processes**
  - Fundamental Aspects of Physical, Chemical and Physicochemical Processes
- **CE 665: Ecological and Biological Principles and Processes**
  - Fundamentals Aspects of Ecological and Biological Processes/Systems
- **CE 666: Air Pollution and Its Control**

Evolution of Our Planet



Earth is estimated to be **4.54 billion years old**, plus or minus about 50 million years

Our Planet

- Planet Earth from above – No Borders, No Walls, or no Passport Control
  - Just a magic blue and white pearl where all life exists
  - All people are the Citizens of the world
  - All people are dependent on each other, rather all forms of life is dependent on each other.

Our Planet

"Planet Earth – is a Giant Self-Regulating System"

- Gaia Hypothesis

Our Planet

Fascinating Aspects:

– The existence of Ozone Layer in the upper atmosphere, crucial for sheltering living organisms from the harmful UV radiations

– Stabilization of the proportion of oxygen at approximately 21%, balanced through production and decomposition of organic matter

– Presence of small, but essential, quantities of ammonia in the atmosphere enabling the neutralization of naturally produced sulphur and nitric acid

– The relatively constant air surface temperature in spite of changes in the gaseous composition of the atmosphere and solar radiation, and

– The constancy of the salt content in the oceans at 3- 4 %, even through minerals are constantly added via rivers.

Our Planet

"The other important aspect of a Self-Regulating Capacity of our planet is the ability of living systems on Earth to counteract changes in the external environmental through uptake, metabolism and excretion of substances."

Comparison between Planetary and Human Body

Day & Night	→	***Heart Beats***
Seasons	→	***Breaths***
Tropical Rain Forests	→	***Liver***
Atmosphere & Oceans	→	***Circulatory Systems***

Natural Changes V/S Anthropogenic Influences

"Changes have been taking place" why are we concerned now, and "what is the role of human beings, because they appeared very late"

– Human development has caused wide spread environmental interventions. The effects of technological endeavors have in some cases to fast to control

- **Result:** Degradation of the world's environmental resources which threatens the welfare of the whole planet.

Environmental Degradation

On a Global Scale

- Thousands of tones of topsoil lost every second
- 3000 m square of forests destroyed every second
- 2000 m square of arable land turned into deserts every second, and
- More than 100 species of plants/animals exterminated every day

Environmental Degradation

On a Global Scale

On other hand

"1000 tones of unwanted gases and perhaps another tones of wastes released per second"

This is for what?

"to disproportionately sustain the material wealth of a billion people and barely more than physical survival of the remaining seven billion"

Environmental Degradation

On Our Planet – On a Global Scale

- Developed countries 10% population consumes 10 times more energy, water, and mineral than the rest 90%.
- Under the political and economic conditions of the present global debt crisis, it seems nearly impossible for people in developing countries not to put pressure on nature in order to keep the flow of resources going from South to North.
- If the consumption patterns and the rate associated remain unchanged, reaching the development objectives would mean a roughly five folds increase in the rates of environmental degradation.

Developmental Phases

- Industrial Development
- Environmental Problems
- Environmental Protection

Developmental Phases – Environmental Impacts

- **1800 – 1900 Industrial Revolution**
  - Few, Mainly Local Negative Effects
  - Insignificant Compared with Increase in Material Growth & Simultaneous Environmental Improvements

Developmental Phases – Environmental Impacts

- **1900 – 1950**
  - Deterioration More Extensive
  - Conflict between Economic Growth and Environment
- **1950 – Local, Regional and Global**
  - Negative Environmental Implications
  - Negative Effects >> Benefits of growing Material Wealth
  - Negative Effects ↑ Even when Economic Growth Rate ↓

Terms ……..

Environment

Systems

Environmental Systems

Eco Systems

Environment

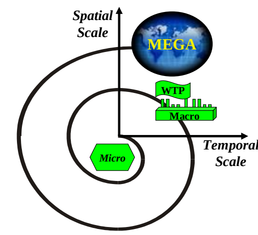
Aggregate of surrounding things, conditions or influences,
especially as affecting or that affects the existence or development of someone or something

[LIVING (*Biotic*)]
or
[NON-LIVING (*Abiotic*)]

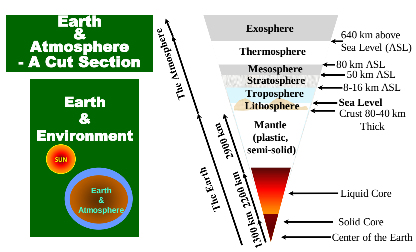
Hardware/ Software ⇨ Physical/Nonphysical

Environment

A continuum of systems involving similar processes over a remarkable range of temporal and spatial scales.



Earth and Atmosphere



Approach to Understanding and Explaining the Environment

Environment is Complex
However, complexity relates more to innate scales and dimensions than to inherent concepts and principles

This premise serving as incentive, approach to understanding and explaining the environment and its myriad systems and processes is to:

- clearly enunciate concepts and related principles.
- initiate analyses on scales at which the principles can be classified and applied rigorously.
- use simple but accurate experimental and mathematical models to articulate those principles, and.
- structure more elaborate models to integrate all relevant principles and thus facilitate their extension to the scale of any system or process of interest.

Important Proverb

"To give a man a fish will feed him for a day, but to train him to fish will feed him for a lifetime"

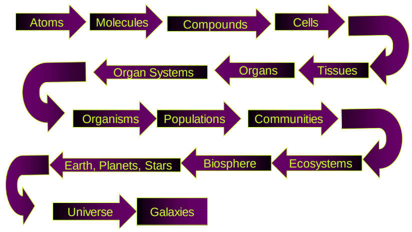
In the same spirit, any one can solve a problem if given the correct algorithm, but it is the knowledge of how to use concepts and principles to construct correct algorithms that enables one to solve any problem

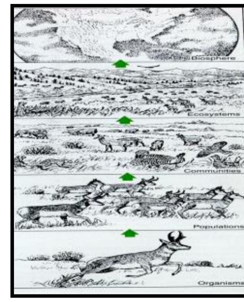
Systems

Collection of objects bonded together in some way so that the collection is more than an independent assemblage of parts

Micro → Macro → Mega Levels (Depending Upon the Boundaries Chosen in a Particular Context)

Micro to Mega Systems





- Galaxies
- Universe
- Earth, Planets, Stars
- Biosphere
- Ecosystems
- Communities
- Populations
- Organisms
- Organ Systems
- Organs
- Tissues
- Cells
- Compounds
- Molecules
- Atomic

Understanding of Changes in Systems

- An understanding of changes in systems is primary in many problems in environmental studies.
- In some cases, very small growth rates may yield incredibly large numbers in modest periods of time.
- It may be possible to compute an average residence time for a particular resource and use this information to develop sound management principles.
- Recognition of positive and negative feedback in systems, and calculation of growth rates and residence times, enable predictions concerning resource management.
- It is important to understand the ways in which physical and biological processes, with or without human interference, may modify ecosystems and Earth.

Systems

- Systems may be open or closed. A system that is open in regard to some factor exchanges that factor with other systems. A system that is closed in regard to some factor does not exchange that factor with other systems.
- Systems respond to inputs and have outputs. Our body, for example, is a complex system. If we see a snake in this classroom, the sight of the snake is an input. Our body reacts to that input – the adrenalin level in our blood goes up, our heart rate increases, and so on. Our response, perhaps moving away or arresting/killing the snake – is an output.

Changes in the System

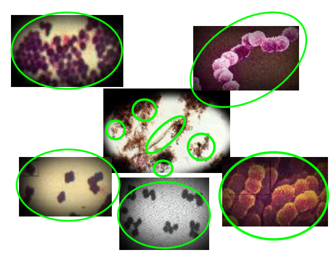
- Changes in natural systems may or may not be predictable, but anyone looking for solutions to environmental problems should be recognized such changes.
- By using rates of change or input/output analysis of systems, we can derive an average residence time for such factors. The average residence time is a measure of the time it takes for the total stock or supply of a particular material, such as a resource, to be cycled through the pool.

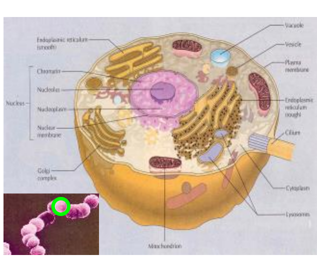
Understanding Systems

- Solutions to environmental problems often involve an understanding of systems and rates of change.
- A system is a set of components or parts functioning together to act as a whole.
- In environmental studies, at every level, one deals with complex systems; thus, it is important to understand certain basic characteristics of every system. A single organism is a system. A sewage treatment plant is a system. A city can be a system. Earth is a system.

Environmental Systems - Analysis Approach

- All systems are comprised by subsystems; mega-scale systems by macro-scale systems, and macro-scale systems by micro-scale systems. This is why many processes can be influenced at the macroscopic scale by similar microscopic mass transfer phenomenon.
- The most fundamental analysis of any system has its origins ultimately at the molecular level and must provide that there is a continuity of principles derived from this scale to the full scale of the system.





Life on the Planet Earth

- Earth as a planet has been profoundly altered by life.
- Earth's air, oceans, soils, sedimentary rocks are very different from what they would be on a lifeless planet.
- In some ways, life controls the makeup of the air, oceans, and sediments.
- It has greatly changed Earth's surface during the last 3 billion years and continues to control and modify

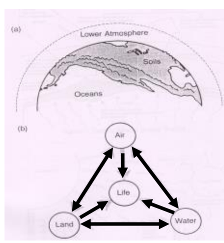
Biosphere

- It is the region of earth where life exists.
- It extends from the depths of ocean to the summit of mountains, but most life exists within a few meters of Earth's surface.
- The biosphere includes all of life, the lower atmosphere, and the oceans, rivers, lakes, soils, and solid sediments that are in active interchange of materials with life.

All living things require energy and materials. In the Biosphere, energy is received from the sun and the interior of Earth, and is used and given off while materials are recycled.

Life & Land-Water-Air Interaction

The Biosphere is a linked system, all its parts are connected



Fundamental Principles: Uniformitarianism

- Earth and its life forms have changed many times, but certain processes necessary to sustain life and a livable environment have occurred throughout much of history.
- The principle that present physical and biological processes that are forming and modifying our Earth can help explain the geologic and evolutionary history of Earth is known as the doctrine of uniformitarianism.
- Simply stated as "the present is the key to the past"
- Uniformitarianism does not demand or even suggest that the magnitude and frequency of natural processes remain constant with time. Obviously, some processes do not extend back through all of geological time.

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Environmental Unity means that it is impossible to do only one thing; that is, everything affects everything else. Many aspects of environment are closely related. Disruptions or changes in one part of the system will often have secondary and tertiary effects within the systems or will even affect adjacent system. Earth and its ecosystems are complex entities in which any action has several or many effects.

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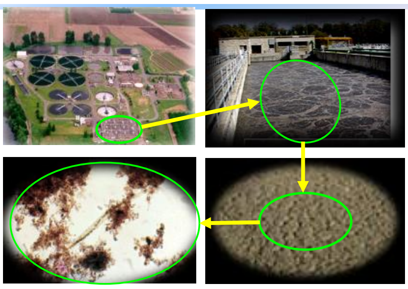

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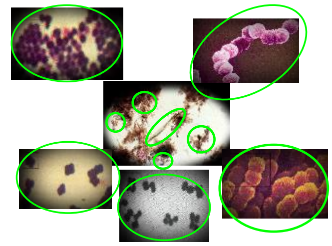

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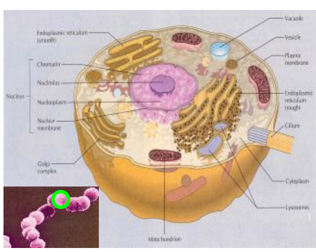

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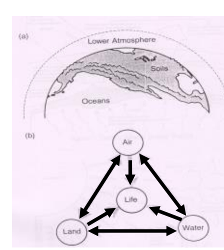

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  - Thus understanding of chemistry is essential to understanding of living organisms.
- **Biochemistry:** Branch of chemistry, that deals specifically with chemistry in relation to life processes, such as chemical reactions involved in respiration and photosynthesis.

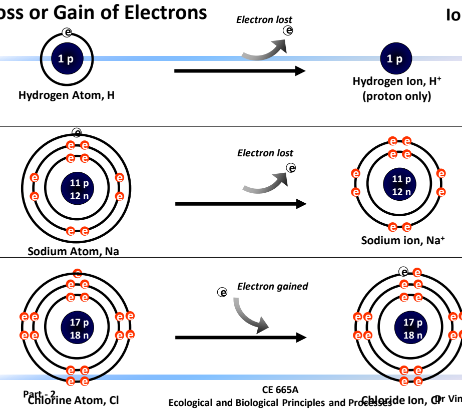
Living Organisms

Contains atoms and molecules as their most basic structural units

- The kind of interaction between atoms and molecules determines the fundamental qualities of compound such as solubility, acidity, etc.
- Microorganisms depend on soluble nutrients and are affected by their environment.
- Important chemical substances in living organisms are based on the element carbon, and include carbohydrates, lipids, proteins and nucleic acid.
- Biochemical processes (reactions) depend on special substances called enzymes, which greatly increase the speed at which a specific reaction occurs.
- By balancing the production and utilization of thousands of chemical, each microorganisms can adjust, and even contribute, to its surroundings.

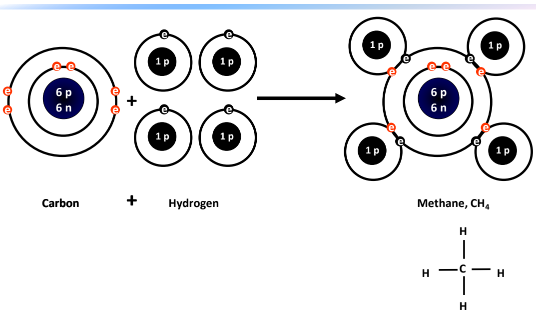
Loss or Gain of Electrons

Ionic Bond



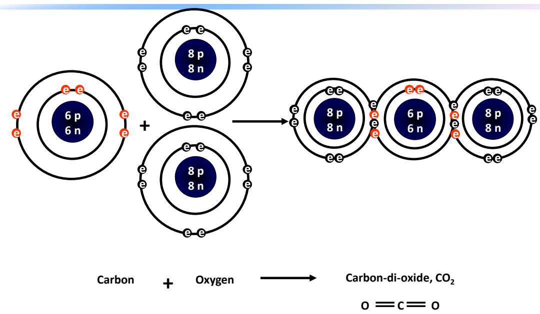
Sharing of Electrons

Covalent Bond

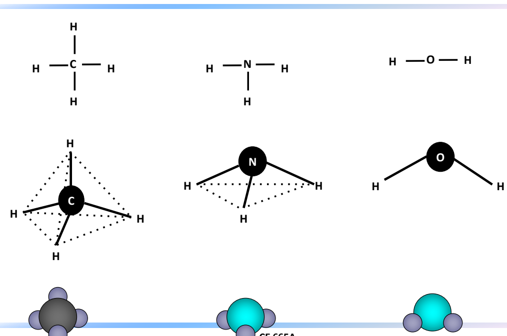


Sharing of Electrons

Covalent Bond

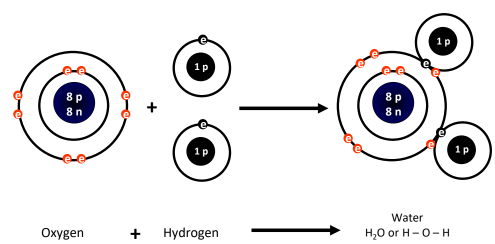


Geometric configuration of chemical bonds around carbon, nitrogen, and oxygen atom

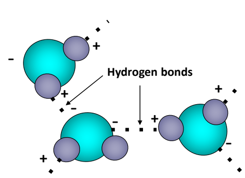


Sharing of Electrons – Unequal

Covalent Bond



Hydrogen Bond



Water molecules can be linked by hydrogen bonds. The small spheres are hydrogen atoms; the large spheres are oxygen atoms

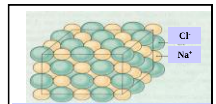
Importance of Water

- 80 to 90% of the weight of cell is actually water.
- Tends to resist heating/cooling.
- Fluid medium for most biochemical reactions.
- Direct participation in biochemical activities hydrolysis (splitting by water).
- Excellent solvent.

Solubility of Compounds in Water

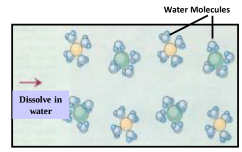
- The ability of ions to attract water molecules indicates that the ions are hydrophilic (water loving).
- Compounds that dissociate into ions are considered ionizable, and the presence of ionic groups confers water solubility on molecules.

Solubility in Water



Crystalline sodium chloride

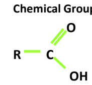
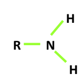
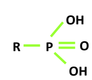
A sodium chloride crystal dissolves readily in water because the water molecules, which are electrically polar, become oriented to form hydration shells around the sodium ions and chloride ions and chloride ions. This helps to keep the ions separated from the another.



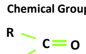
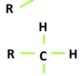
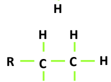
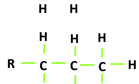
Solubility of Compounds in Water

- Polar & Ionizable Compounds → Soluble
- Non-polar Compounds → Insoluble (e.g. Oil, fats)
  - Soluble in non-polar solvents (no bonds between non-polar molecules, only aggregate)
- Amphipathic Compounds → both polar/ionized groups & non-polar region.
  - Soaps hydrophilic group inside and hydrophobic group outside
- Phospholipid → play an important role

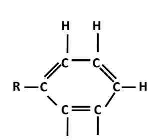
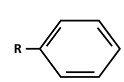
Functional Groups

Chemical Group*	Abbreviated Form	Name	Properties
	R — COOH	Carboxyl group (acidic)	Ionizes to $R-COO^{-}$
	R — NH_2	Amino group (basic)	Ionizes to $R-NH_3^{+}$
	R — PO_3H_2	Phosphate group (acidic)	Ionizes to $R-PO_3^{2-}$
R — OH	---------------	Hydroxyl group	Polar

Functional Groups

Chemical Group*	Abbreviated Form	Name	Properties
	R — CO — R	Carbonyl group (keto group)	Polar
	R — CH_3	Methyl group	Nonpolar
	R — CH_2 — CH_3	Ethyl group	Nonpolar
	R — CH_2 — CH_2 — CH_3	Propyl group	Nonpolar

Functional Groups

Chemical Group*	Abbreviated Form	Name	Properties
		Phenyl group	Nonpolar

Role of Acid, Bases, pH Buffer

- Water ionizes poorly one liter 55.55 mol of water but only 10^{-7} mol is ionized out of 555,500,000 molecules only one molecule is separated to H & OH.

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Contain atoms and molecules as their most basic structural units

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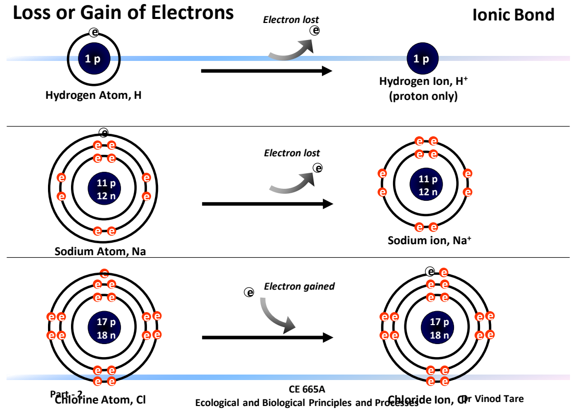
- Microorganisms depend on soluble nutrients and are affected by their environment.
- Important chemical substances in living organisms are based on the element carbon, and include carbohydrates, lipids, proteins and nucleic acid.
- Biochemical processes (reactions) depend on special substances called enzymes, which greatly increase the speed at which a specific reaction occurs.
- By balancing the production and utilization of thousands of chemicals, each microorganism can adjust, and even contribute, to its surroundings.

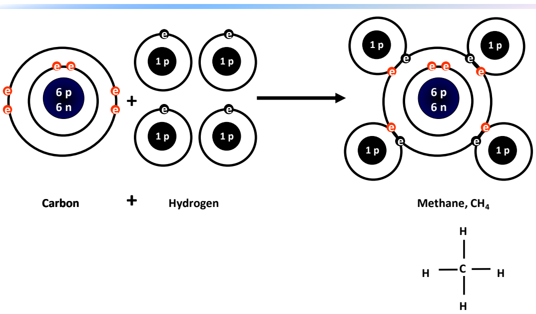
Loss or Gain of Electrons

Ionic Bond



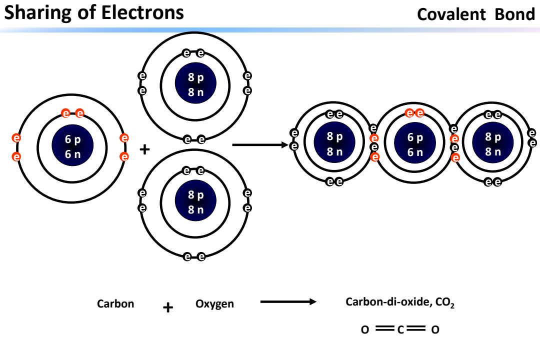
Sharing of Electrons

Covalent Bond

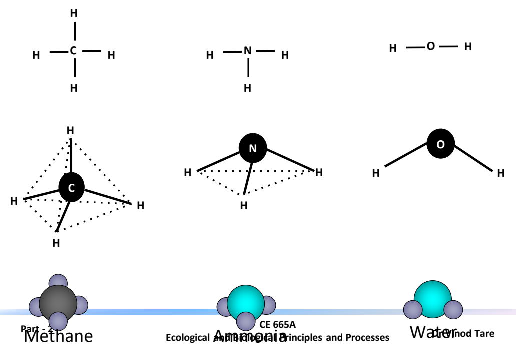


Sharing of Electrons

Covalent Bond

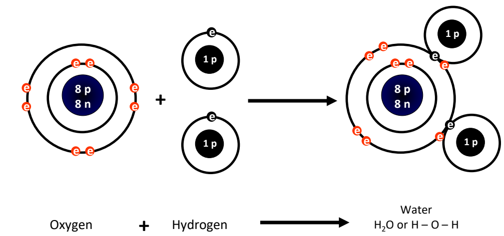


Geometric configuration of chemical bonds around carbon, nitrogen, and oxygen atom

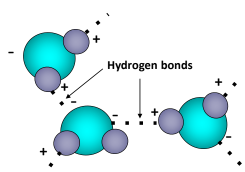


Sharing of Electrons – Unequal

Covalent Bond



Hydrogen Bond



Water molecules can be linked by hydrogen bonds. The small spheres are hydrogen atoms; the large spheres are oxygen atoms

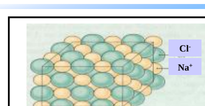
Importance of Water

- 80 to 90% of the weight of cell is actually water.
- Tends to resist heating/cooling.
- Fluid medium for most biochemical reactions.
- Direct participation in biochemical activities hydrolysis (splitting by water).
- Excellent solvent.

Solubility of Compounds in Water

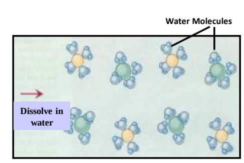
- The ability of ions to attract water molecules indicates that the ions are hydrophilic (water loving).
- Compounds that dissociate into ions are considered ionizable, and the presence of ionic groups confers water solubility on molecules.

Solubility in Water



Crystalline sodium chloride

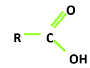
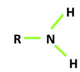
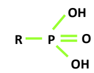
A sodium chloride crystal dissolves readily in water because the water molecules, which are electrically polar, become oriented to form hydration shells around the sodium ions and chloride ions and chloride ions. This helps to keep the ions separated from the another.



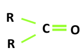
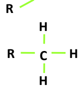
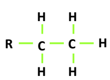
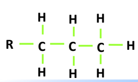
Solubility of Compounds in Water

- Polar & Ionizable Compounds → Soluble
- Non-polar Compounds → Insoluble (e.g. Oil, fats)
  - Soluble in non-polar solvents (no bonds between non-polar molecules, only aggregate)
- Amphipathic Compounds → both polar/ionized groups & non-polar region.
  - Soaps hydrophilic group inside and hydrophobic group outside
- Phospholipid → play an important role

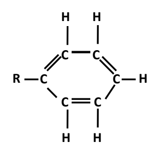
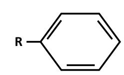
Functional Groups

Chemical Group*	Abbreviated Form	Name	Properties
	R — COOH	Carboxyl group (acidic)	Ionizes to $R - COO^-$
	R — NH_2	Amino group (basic)	Ionizes to $R - NH_3^+$
	R — PO_3H_2	Phosphate group (acidic)	Ionizes to $R - PO_3^{2-}$
R — OH	---------------	Hydroxyl group	Polar

Functional Groups

Chemical Group*	Abbreviated Form	Name	Properties
	R — CO — R	Carbonyl group (keto group)	Polar
	R — CH_3	Methyl group	Nonpolar
	R — CH_2 — CH_3	Ethyl group	Nonpolar
	R — CH_2 — CH_2 — CH_3	Propyl group	Nonpolar

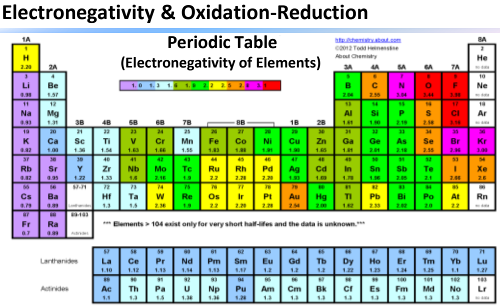
Functional Groups

Chemical Group*	Abbreviated Form	Name	Properties
		Phenyl group	Nonpolar

Role of Acid, Bases, pH Buffer

- Water ionizes poorly one liter 55.55 mol of water but only 10^{-7} mol is ionized out of 555,500,000 molecules only one molecule is separated to H & OH.

Electronegativity & Oxidation-Reduction



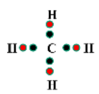
Electronegativity measures the tendency of an atom to attract a shared pair of electrons (or electron density)

Oxidation-Reduction

Oxidation Number

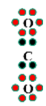
Oxidation number of an atom in a molecule is the charge remaining on an atom assuming all bonds are broken with shared electrons remaining with the more electronegative atom.

Example:



Oxidation number of C in CH_4:
C has a valency of 4, i.e., it is neutral with the 4 "black" electrons in the outer shell Since C is more electronegative that H, when bonds are broken in CH_4, the "red" electrons remain with C. Hence C now has a charge of -4. Hence oxidation number of C is -4

Oxidation number of C in CO_2 :
Since O is more electronegative than C, when bonds are broken, all "black" atoms of C are taken by O. Hence C now has charge of +4. Hence Oxidation number of C is +4.



Oxidation-Reduction

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ **: Methane is Oxidized to CO_2**

$$CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e \qquad \text{Eq. 1}$$
$$O_2 + 4H^+ + 4e \rightarrow 2H_2O \qquad \text{Eq. 2}$$

$$\text{Eq. 1} + 2.(\text{Eq. 2})$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Eq. 1:

- Consider an atom (C), which was associated with atoms which are more electropositive. The carbon side of the molecule is thus more negative (less positive).
- After reaction, C atom is now associated with atoms which are relatively more electronegative. The carbon side of the atom is now less negative (more positive) than before.
- Under the circumstances, Carbon atom is considered to be oxidized. Oxidation is thus associated with release of negative charge, i.e., electrons.

Oxidation-Reduction

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ **: Methane is Oxidized to CO_2**

$$CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e \qquad \text{Eq. 1}$$
$$O_2 + 4H^+ + 4e \rightarrow 2H_2O \qquad \text{Eq. 2}$$

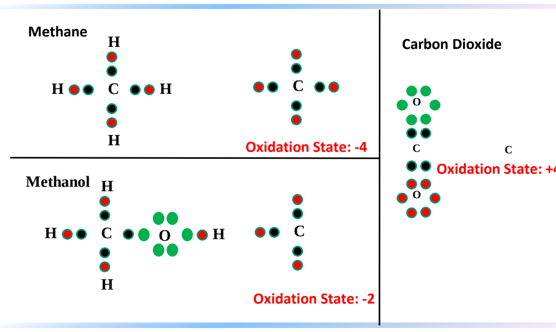
$$\text{Eq. 1} + 2.(\text{Eq. 2})$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Eq. 2

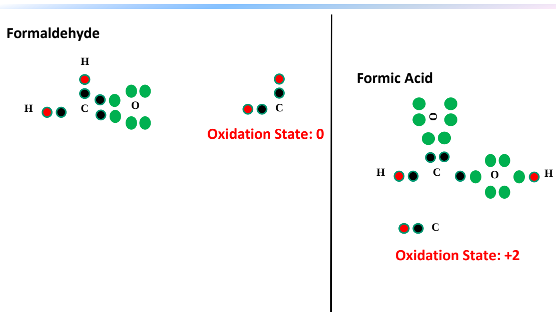
- Consider an atom (O), which is associated with another O atom.
- After reaction it is now associated with atoms which are more electropositive. Thus the oxygen side of the atom is now more negative (less positive) than before.
- Under the circumstances, O atom is considered to be reduced. Reduction is thus associated with acceptance of electrons,

The release or acceptance of electrons must be balanced for an oxidation – reduction reaction

Oxidation-Reduction



Oxidation-Reduction



Oxidation Number of Common Atoms

1. The oxidation number of an atom is zero in a neutral substance that contains atoms of only one element. Thus, the atoms in O_2, O_3, P_4, S_8, and metals all have an oxidation number of 0.
2. The oxidation number of simple ions is equal to the charge on the ion. The oxidation number of sodium in the Na^+ ion is +1, for example, and the oxidation number of chlorine in the Cl^- ion is -1.
3. The oxidation number of hydrogen is +1 when it is combined with a *nonmetal* as in CH_4, NH_3, H_2O, and HCl.
4. The oxidation number of hydrogen is -1 when it is combined with a *metal* as in. LiH, NaH, CaH_2, and $LiAlH_4$.
5. The metals in Group IA form compounds (such as Li_3N and Na_2S) in which the metal atom has an oxidation number of +1.
6. The elements in Group IIA form compounds (such as Mg_3N_2 and $CaCO_3$) in which the metal atom has a +2 oxidation number.

Oxidation Number of Common Atoms

7. Oxygen usually has an oxidation number of -2. Exceptions include molecules and polyatomic ions that contain O-O bonds, such as O_2, O_3, H_2O_2, and the O_2^{2-} ion.
8. The elements in Group VIIA often form compounds (such as AlF_3, HCl, and $ZnBr_2$) in which the nonmetal has a -1 oxidation number.
9. The sum of the oxidation numbers in a neutral compound is zero. H_2O: 2(+1) + (-2) = 0
10. The sum of the oxidation numbers in a polyatomic ion is equal to the charge on the ion. The oxidation number of the sulfur atom in the SO_4^{2-} ion must be +6, for example, because the sum of the oxidation numbers of the atoms in this ion must equal -2. SO_4^{2-}: (+6) + 4(-2) = -2
11. Elements toward the bottom left corner of the periodic table are more likely to have positive oxidation numbers than those toward the upper right corner of the table. Sulfur has a positive oxidation number in SO_2, for example, because it is below oxygen in the periodic table. SO_2: (+4) + 2(-2) = 0

Depending on the compound, atoms can have multiple oxidation states

1. C can have oxidation states from +4 (as in CO_2) to -4 (as in CH_4)
2. Cr can commonly have oxidation states of +3 and +6
3. As can commonly have oxidation states of +3 and +5
4. P can commonly have oxidation states of -3 to +5
5. Mn can commonly have oxidation states of +2, +4 and +7
6. N can commonly have oxidation states of -3, +2, +3, +4, +5
7. S can commonly have oxidation states of -2, +4, +5, +6
8. Cl can have oxidation states of -1, +1, +2, +3, +4 …+7

Fractional Oxidation Numbers

The oxidation numbers are integers, but in some cases, they appear to be fractional numbers. For example in Fe_3O_4, oxidation number of Fe appears to be, 3Fe + (-8) = 0; Fe = +8/3. This means that all three atoms of Fe in Fe_3O_4 do not have same oxidation number. For Fe_3O_4, two Fe atoms have an oxidation number of +3 and one of +2, which makes the total oxidation number of Fe = +8/3.

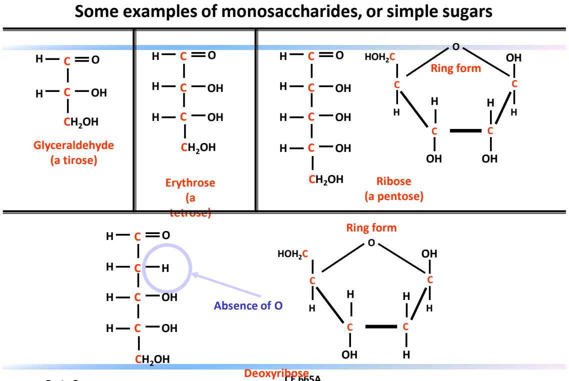
Important Biological Compounds

- Cell of all living organisms, from microbes to humans, are composed of chemical compounds.
- In-organics as well as organic compounds, but organic compounds have the most biological significance.
- Most of organic compounds can be grouped into one of four main categories
  - Carbohydrates,
  - Lipids
  - Proteins and
  - Nucleic acids

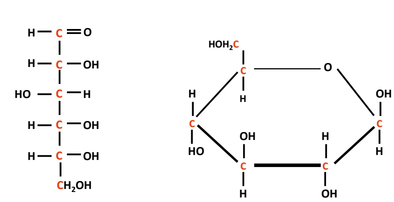
Carbohydrates

- Sugars and starches are carbohydrates
- Primary source of energy in cell
- Some carbohydrates are also found in cell walls, while others serve as food storage and act as building blocks for proteins, lipids and nucleic acids.
- General formula $(CH_2O)_n$ (any whole number)
- They can be quite simple in structure or contain many molecules arranged in complex ways.
- Simplest carbohydrates are Monosaccharides or (simplest sugars)
- Large number of monosaccharides linked together are referred to as polysaccharides → As in a molecule of starch

Some examples of monosaccharides, or simple sugars

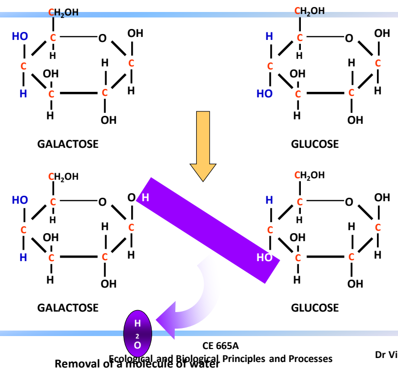


Some examples of monosaccharides, or simple sugars

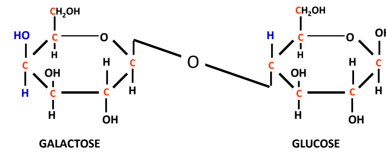


Glucose
(a hexose)

Di- / Poly- saccharides

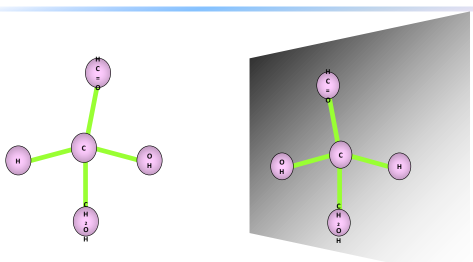


Di- / Poly- saccharides



Lactose
(a disaccharide)

Isomers – Optical Isomers



Glyceraldehyde has an asymmetric carbon atom and thus can exist as two optical isomers, the D and L forms, which are mirror images of each other.

Lipids

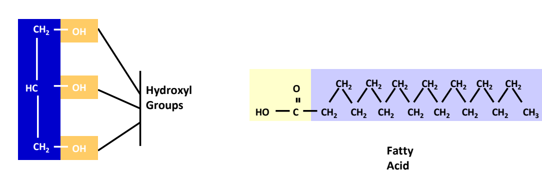
- Organic substances soluble in non-polar solvents such as acetone, chloroform, ether or benzene.
- Most lipids are insoluble in water
- Composed mainly of H and C atoms and less of other elements such as O, N and P
- There are three major categories of lipids (biologically important) based on differences in structure: fats, phospholipids, and sterols.

Fats

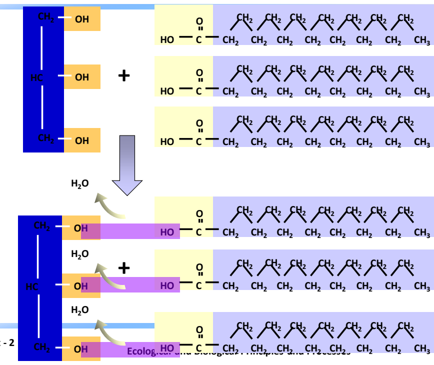
- Fats are simple lipids made of two kinds of building blocks: glycerol and fatty acids
- Fats are formed when three molecules of fatty acids are attached by an enzymes to one molecule of glycerol
- Hence called as triglycerides

Fats

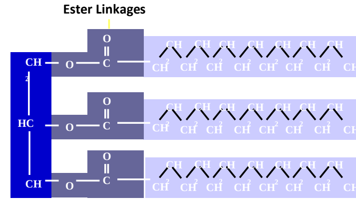
Glycerol molecules and fatty acid molecules are the building blocks of fats.



Three fatty acid molecules are linked to one molecule of glycerol by removing three molecules of water, to form one molecule of fat, i.e. a triglyceride



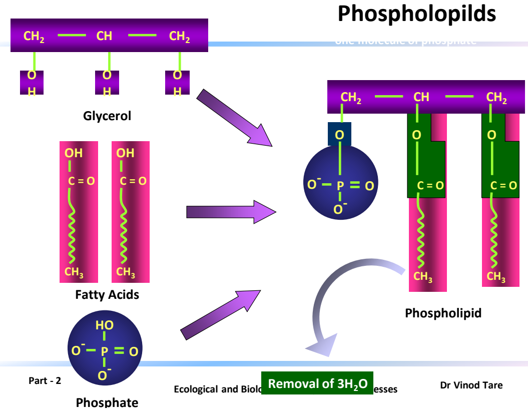
Fats



Phospholopilds

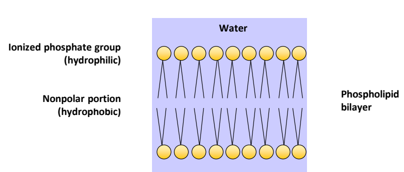
- Phospholipids are complex lipids, are important component of cell membranes. (for e.g. 22 million phospholipid molecules are found in *Echerichia coli* (a single cell bacterium)
- Only two molecules of fatty acids are linked to a molecule of glycerol
- A phosphate group is linked to the glycerol

Phospholopilds



Phospholopilds

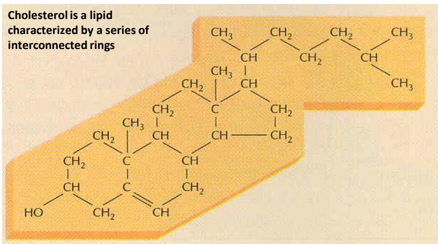
When placed in water, the amphipathic phospholipid molecules form a bilayer, with the non polar hydrocarbon chains of the fatty acid facing inward and the negatively charged phosphate groups facing outward.



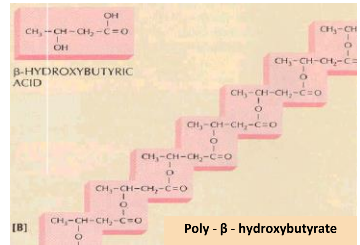
Sterols

- Highly non-polar, consist mainly of several interconnected rings made of carbon atoms.
- Animals use them to synthesize vitamin D and steroid hormones.
- Found in membranes of eucaryotic cells and a few bacteria.
- The compound cholesterol, a normal component of some membranes, is a member of this group of lipids i.e. sterol.
- Several anti fungal drugs combine with sterols in membrane of fungus cells, eventually killing the cells.

Cholesterol



Poly- β- hydroxybutyrate



Poly- β- hydroxybutyrate is a chain of many molecules of β hydroxybutyric acid linked together by removal of water molecules, only a small portion of the entire chain is shown

Other lipids

- Lipids in chlorophyll, those in cell walls of the bacterium that causes tuberculosis, and those that provide the red and yellow pigments of same microorganisms
- A lipid called PHB (poly-B-hydroxybutyrate) occurs only in certain bacteria as a reserve source of carbon and energy
- Insoluble in water and even in some non-polar solvents, such as alcohol and ether
- Soluble in hot chloroform.

Proteins

- In terms of weight, proteins surpass lipids and carbohydrate in a cell.
- Multiple functions: some may be enzymes, the catalytic agents that control all biochemical processes; others may be part of cell structures, such as flagella; or they may control nutrient transport through membranes; Toxins produced by cells are proteins.
- Composed of amino acids (building blocks)

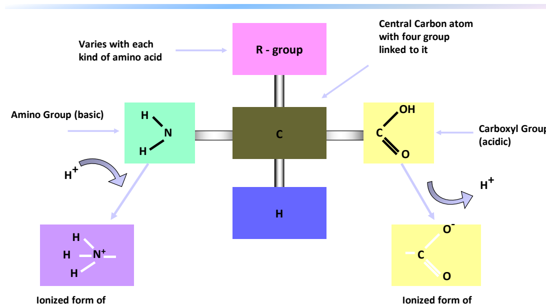
Amino Acids

The 20+ kinds of amino acids from which proteins are formed; all have one part of their structure in common but differ in their R groups. The central carbon is asymmetric if all four groups linked to it differ from one another, as is the case for most amino acids.

A standard abbreviation for the name of each amino acid is used.

General Structure of an Amino Acid

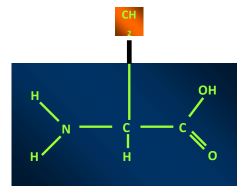
The amino group is basic and can take up a hydrogen ion to become positively charged, whereas a carboxyl group is acidic and can liberate a hydrogen ion to become negatively charged.



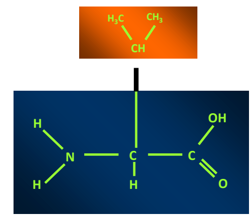
Amino Acids

- An amino group, $-NH_2$, can take up H ion, basic group.
- A carbonyl group, -COOH, can release H ion; acidic group.
- A hydrogen atom; and
- An "R" group which varies with each kind of amino acid.
- Amino acids (20 in number) consist of four chemical groups attached to carbon atom. Several amino acids linked together in a chain from a protein molecule.
- In most amino acids, Carbon atom is asymmetric, since the four group differ from one another.
- The only exception is glycine – two groups are H atoms .
- Because of asymmetric carbon atom, an amino acid can exist as either of two optical isomer, mostly L isomer in living organisms, D isomers are rare, although certain ones do occur in cell walls of bacteria.

Amino Acids

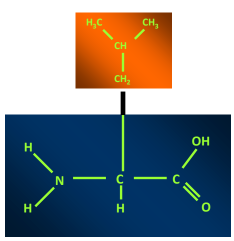


Alanine (Ala)

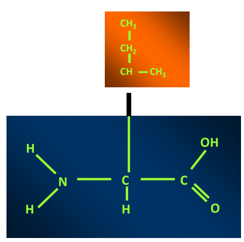


Valine (Val)

Amino Acids

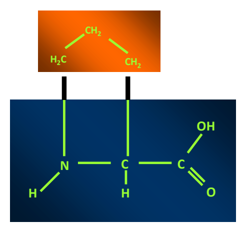


Leucine (Leu)

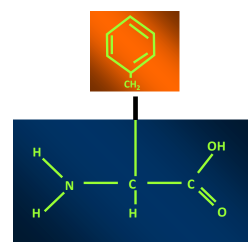


Isoleucine (Ile)

Amino Acids

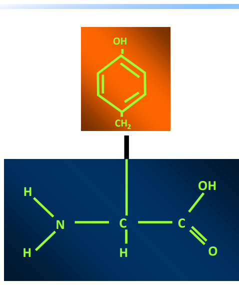


Proline (Pro)

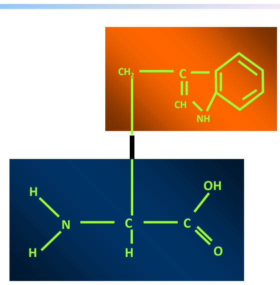


Phenylalanine (Phe)

Amino Acids

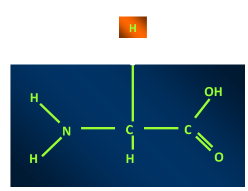


Tyrosine (Tyr)

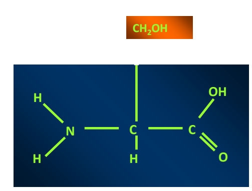


Tryptophan (Trp)

Amino Acids

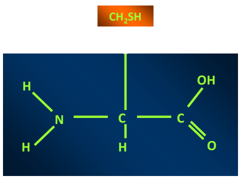


Glycine (Gly)

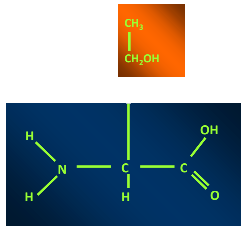


Serine (Ser)

Amino Acids

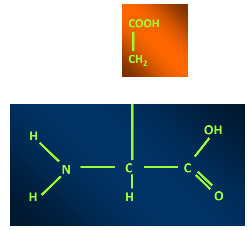


Cysteine (Cys)

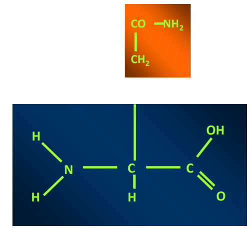


Threonine (Thr)

Amino Acids

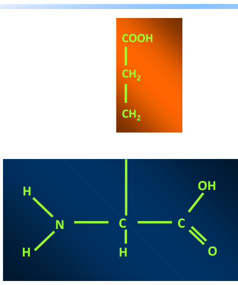


Aspartic acid (Asp)

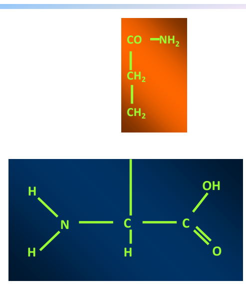


Asparagine (Asn)

Amino Acids

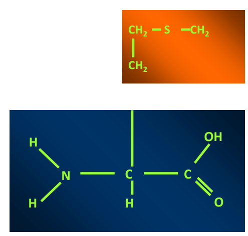


Glutamic acid (Glu)

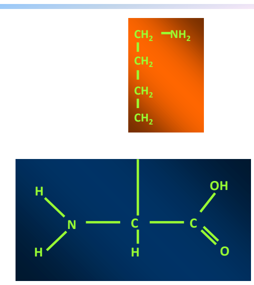


Asparagine (Asn)

Amino Acids

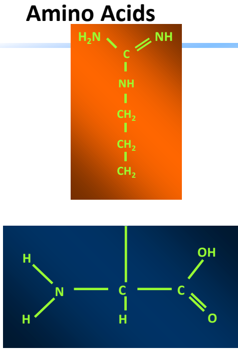


Methionine (Met)

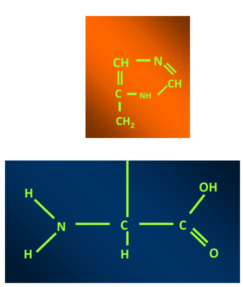


Lysine
(Lys)

Amino Acids



Arginine (Arg)



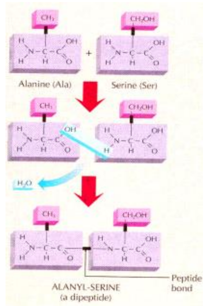
Histidine (His)

Peptide Bond

- Formed by removal of water molecule, tie together amino acids to form a long chain, called a polypeptide chain.
- Proteins consist of one or more of these polypeptide chains, which may change in length from fewer than 100 amino acids to more than 1000.

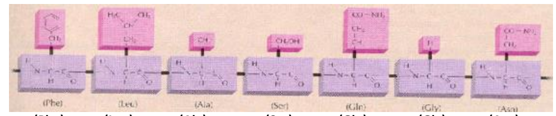
Di-peptide

By removing a molecule of water, two amino acids can be linked together to form a dipeptide.



Polypeptide

Many amino acids can be linked together to form a long chain, called a polypeptide.

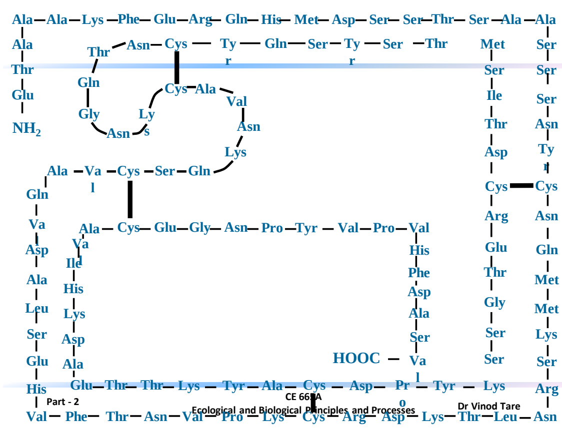


Portion of polypeptide chain

Levels of Protein Structure

A living cell contain 1000 or more different kinds of proteins, and each kind has its own unique sequence of amino acids. The amino acids sequence is called the primary structure of the protein.

(for e.g. ribonuclease contains 124 amino acids in a specific sequence).

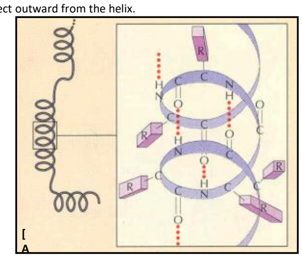


Protein Structure

- **Secondary structure:** A polypeptide chain can fold into a specific shape, much like a ribbon. Some portions of chain may form a coil, while others may form a side-by-side arrangements or other configurations. These forms constitute the secondary structure and are due to H bonding between polar –C=O and –NH groups along the chain.
- **Tertiary structure:** Overall folding of molecules into a specific shape, caused by interaction between different types of polypeptide chains. For instance, di sulfide bridges or bonds between sulphur ions contribute to the tertiary structure by connecting cysteine molecules located in different regions of the polypeptide chain.
- **Quaternary Structure:** Some proteins contain two or more polypeptide chains for their proper activity. This combination of polypeptide chains constitutes the quaternary structure. For example, the blood protein hemoglobin contains four polypeptide chains.

Protein Structure

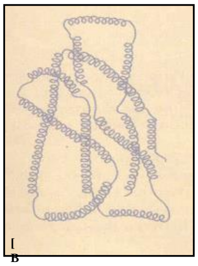
[A] Secondary structure of a protein. Portions of the polypeptide chain from an alpha helix due to hydrogen bonding (•••••) between –C=O and –NH groups of the peptide bonds. (for simplicity, only the hydrogen atoms actually involved in the hydrogen bonding are shown.) The R Groups of the amino acids in the chain project outward from the helix.



[A]

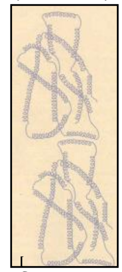
Protein Structure

[B] The tertiary structure of a protein is determined by interactions between portions of the chain



Protein Structure

[C] Quaternary structure of a protein. The protein shown here is composed of two identical polypeptide chains, but some proteins are composed of several different kinds of chains.



End of Part 2: Thank You

Questions, Comments & Suggestions may be sent to
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